ESPC Common Model Architecture
Earth System Modeling Framework (ESMF)
Software and Application Development

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LONG-TERM GOALS

To expedite the development of numerical weather prediction (NWP) systems, the National Unified Operational Prediction Capability (NUOPC) was established between NOAA and Navy to develop a common software architecture for easy and efficient interoperability. The overarching goal of NUOPC is to accelerate the improvement in the U.S. National environmental prediction capability, focusing initially on the global model enterprise. Improvements in prediction capability are expected to result in better environmental situation awareness, severe weather warnings (hurricanes, tornadoes, snow storms), better cost avoidance for weather sensitive industries (agriculture, transportation, utilities, and defense), and better informed decision making for industry, defense and the general public. These goals will be achieved through model development under a common model architecture and other software-related standards in this project.

OBJECTIVES

NUOPC proposes to accelerate improvement of our national prediction capability in the following ways: (1) Implementing a global atmospheric multi-model ensemble system designed to enhance predictive capability and to provide probabilistic prediction for severe weather events; (2) Clearly articulating operational requirements and articulating a corresponding National research agenda; (3) Sharing the development efforts and promote collaborations of numerical weather prediction (NWP) systems among the operational agencies; (4) Accelerating the transition of new technology into the operational centers; (5) Designing requirements and standards of future NWP systems, (6) Accelerating the development and transition of Navy global ensemble prediction system and its participation in the national multi-model ensemble system, and, (7) Implementing ways to enhance broad community participation in addressing the National research agenda.

APPROACH

This project will support improvements and optimizations to the Earth System Modeling Framework (ESMF) library and NUOPC standard by NOAA/ESRL for an efficient coupling capability. ESMF is infrastructure for building and coupling weather, climate, coastal, and other applications. The NUOPC Layer software is a small set of interfaces that provide templates and conventions that standardize ESMF implementation and increase the interoperability of components. The improved system will be adopted and tested by NRL for the Navy coupled system. The ESMF development team will provide support for the implementation.

WORK COMPLETED

A significant achievement during FY15 was the formalization of the Earth System Prediction Suite (ESPS), a set of codes including regional and global Navy coupled models that conform to the NUOPC Layer conventions. Other coupled codes in the ESPS originate from NASA, NOAA, and community modeling efforts, and support for creation of the suite was shared by sponsors from other agencies. ESPS represents an unprecedented level of coordination among U.S. centers and new opportunities for collaboration, research to operations, and multi-model ensemble development. The achievement was documented in an article accepted for publication in the Bulletin of the American Meteorological Society (Theurich et al. 2015).

Software development during FY15 focused on improvements to the ESMF and NUOPC Layer software in preparation for the ESMF v7.0 release, currently expected in October 2015. The NUOPC Layer interfaces were reviewed and standardized with respect to syntax and behavior, in conjunction with the NUOPC/ESPC Content Standards Committee. The flexibility of the NUOPC Layer was increased in a number of ways; for example, generic NUOPC Connectors can now be customized by setting metadata Attributes. This makes it easy to invoke options like switching bit-for-bit mode on. There were also many improvements to the ESMF software, including added support for observational data streams as the destination for grid remapping operations. In addition, work performed during FY15 included user support of ESMF and the NUOPC Layer for Navy applications.

The next sections describe in more detail the features added to ESMF and the NUOPC Layer in preparation for the ESMF 7.0 release, and activities related to application development and user support.

RESULTS

1) ESMF and NUOPC FY15 Release Preparation

The upcoming ESMF v7.0 release represents the conclusion of a development cycle that has been informed by the adoption of ESMF and the NUOPC Layer in a variety of models, including wave, space weather, sea ice, atmosphere, ocean, land, hydrology, and other components. Most development related to the release is complete, and delivery is anticipated in October 2015. The features described here are available in development snapshots of the ESMF/NUOPC software.

An important feature was added to support data assimilation applications. Observational data streams (called Location Streams in ESMF) can now be used as the destination in ESMF grid remapping methods. This enables the grid remapping to be used as an observation operator, where the source grid

can be a logically rectangular grid or mesh. Previously Location Streams were not connected to grid remapping methods at all.

Other features were added to ESMF grid remapping. There is now a new normalization type, destination fraction normalization, available with conservative grid remapping. This option better handles cases where the destination grid isn't entirely contained within the source grid. There is also a new algorithm to compute bilinear interpolation weights in 3D. This algorithm computes weights along lines that follow the curve of a sphere instead of straight lines. This algorithm significantly reduced the error in a space weather interpolation with highly attenuated cells.

Modeling efforts involving adaptive grids are likely to benefit from during-run generation and application of interpolation weights (vs. static generation of weights at the start of a run). ESMF now includes the capability to move an ESMF unstructured Mesh object to a new parallel distribution so that it will work given just the requested distribution of nodes. This is needed to support during-run grid remapping and other capabilities. Improvements were also made to enhance the stability of the algorithm which allows ESMF to generate grid structures from SCRIP format grid files. These changes allow ESMF to generate interpolation weights for some grid files that didn't work previously. Finally, ESMF's conservative interpolation algorithm was extended to work on any concave cell. This option was added to handle a case that U.K. Met Office users needed.

Improvements to the NUOPC Layer software included the review and standardization of calling interfaces; customization of NUOPC Connectors by setting metadata Attributes; introduction of labels to identify components and their phases, instead of indices; and the ability for NUOPC Drivers to add components dynamically, at run time.

Improvements were also made to ESMF I/O and utilities. A parallel I/O library (PIO) is now on by default, on platforms where NetCDF is available. The LogErr class was extended to allow more flexibility with default logs, including closing and reopening under different names.

2) Applications and User Support

Support interactions included the following:

The ESMF grid remapping lead (Oehmke) worked closely with the space weather group led by NRL scientist Fabrizio Sassi to implement a 3D interpolation between an upper atmosphere and ionosphere. The ESMF team resolved an issue in which unexpected unmapped points appeared when regridding from a fine regular grid to the very irregular ionosphere model grid.

Members of the ESMF team also explored a grid remapping issue that Tim Campbell of NRL Stennis reported. Walter Spector of ESMF was able to reproduce failures in the ESMF regrid store methods with PGI 14.10 and OpenMPI 1.6.3 when compiling with -O3. The issue appears to be a communication problem in ESMF's underlying finite element mesh software. Tim identified a workaround which made the issue no longer a showstopper, while the ESMF team continues to investigate.

Gerhard Theurich continued to support James Chen on implementation of the coupled NAVGEM system.

RELATED PROJECTS

6.4 ESPC Coupled Global system, 6.4 NAVGEM.

REFERENCES

Theurich, G., and co-authors, 2015: "The Earth System Prediction Suite: Toward a Coordinated U.S. Modeling Capability," *Bull. of the American Meteor. Soc.*, in press.